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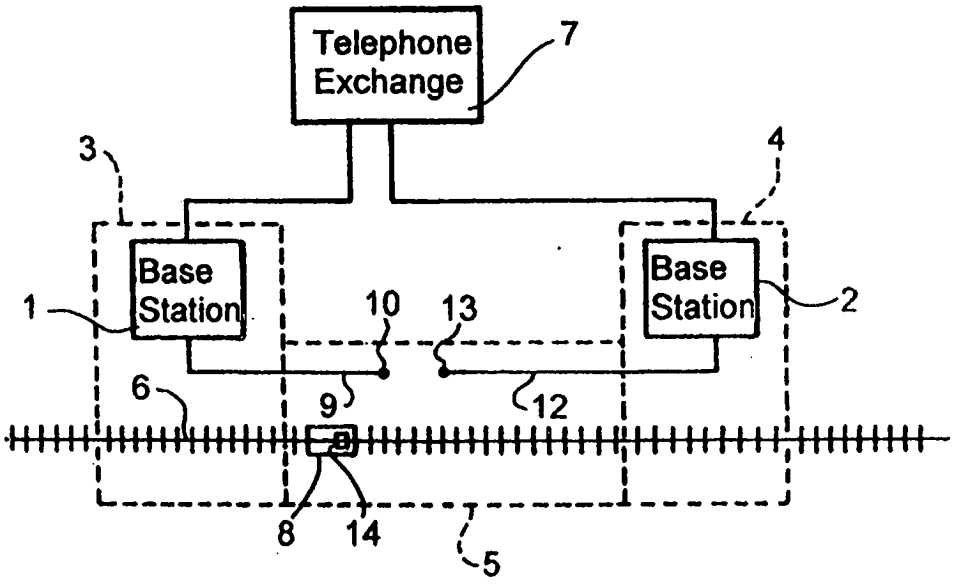

(57) Abstract

A radio telephone system is installed in an underground railway having adjacent railway stations (3, 4), served by respective base stations (1, 2) which also serve adjacent lengths of an interconnecting tunnel bore (5). When an underground train (8) travels from the area served by base station (1) to the area served by base station (2), a telephone call from a mobile telephone (14) on the train is handed over from base station (1) to base station (2). The setting up of the call on one channel between the mobile telephone (14) and the base station (1) causes the infrastructure of the telephone system to reserve the same channel at the next base station (2), ready for the call handover procedure to be effected.

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TITLE: RADIO TELEPHONE SYSTEMS AND METHODS OF OPERATION

This invention relates to radio telephone systems and to methods of operation of such systems.

The invention was devised to facilitate call handover in a radio telephone system installed in an underground railway system. At each railway station, a base station is located. The base station provides radio communication coverage not only for the area of the railway station but also for a length of tunnel bore extending to the adjacent railway station. As an underground train proceeds from one railway station to the adjacent railway station, a mobile radio telephone on a train moves from the area served by a first base station to an area served by the next base station. In order for the call in progress to continue, the call is transferred from the first base station to the next base station. a process known as call handover.

In cellular systems a common method for handover is the use of base station voting. When need for handover is suspected, adjacent sites (ie adjacent base stations) put a receiver to listen for the mobile telephone and measure the link quality. If some adjacent site offers better link quality, a traffic channel is reserved and the mobile is commanded to that channel through the original site.

In underground systems with leaky feeder cable this method cannot be used if the cable system consists of separate cable sections terminating in cut ends. The signal disappears very quickly at the cable cut point and it is not possible to perform the voting and command the mobile telephone to a new channel. Furthermore, the signalling command and the change to a new channel cause additional disturbance and a break in the audio

path.

Another way to perform handover is to let the mobile telephone measure the downlink signal level or quality and request handover when it seems necessary. This mobile-assisted handover can be performed as above with base station voting which causes the same problems.

The mobile telephone can also perform the actual voting or selecting of the new site by measuring the signal quality on the adjacent site control channels. This way the voting receivers are not needed but the procedure is slow even if there are very few adjacent sites and the channels are precisely known. In cut cable systems the mobile does not have enough time to signal the need for handover at the target site before the old site is lost.

The mobile voting handover performance can be improved by letting the mobile telephone transmit and/or receive regularly during the call on a special monitoring channel. If it hears another site on that channel it can request handover immediately through the target site. Each site must have a separate dedicated monitoring receiver and transmitter for that purpose. The regular sampling of the monitoring channel also causes continuous disturbance on the audio path.

According to one aspect of the invention there is provided a radio telephone system comprising two base stations serving respective areas and a mobile radio telephone movable with respect to the base stations so that as the mobile radio telephone moves out of the area served by the first base station and into the area served by the second base station a call handover procedure is effected, and control means for controlling the call handover procedure such that the setting up of a call on one channel between the mobile telephone and the first base station causes the reservation of said one channel at the second base station, ready for the call handover procedure to be effected.

Preferably, the system is installed in an underground railway system. In this case, the base stations may be located at adjacent railway stations of the underground railway system, a tunnel bore interconnecting the railway stations and being served by radiating

cables extending into the bore from the respective base stations.

According to another aspect of the invention there is provided a method of effecting call handover in a radio telephone system, comprising setting up a call on an available channel between a mobile telephone and a first base station and reserving the same channel at a second target base station, ready for call handover when the mobile telephone moves from an area served by the first base station to an area served by the target base station.

On call handover, the channel may be released at the first base station but preferably the transmitter at the first base station is switched off and the receiver at the first base station assumes the standby mode. Preferably, on call set-up the channel is reserved at each of a plurality of possible target base stations, on call handover to a particular target base station the channel being released at the remaining target base stations.

In the preferred embodiment, the mobile telephone monitors received signal strength and transmits a handover request signal if the received signal strength falls below a predetermined level, the handover request signal being detected at the target base station and initiating call handover including the steps turning on a transmitter of the target base station and turning off the transmitter of the first base station.

The new handover method is optimised for the underground system where the adjacent sites do not interfere with each other due to the cut cable principle. When handover is anticipated then the same channel is reserved on all adjacent (target) sites. As the cable cut area is not completely free of interference if the same channel is used on both sides of the cut, the transmitter on the target sites is not switched on.

The receivers are all active and the audio signals are added together in the system. When the mobile telephone approaches the cut area its transmission can be heard from both receivers but there is no interference as the signals are summed after demodulation. In the uplink direction the handover becomes truly seamless.

In the downlink direction the base station signal disappears quickly at the cable cut. The

system must be able to switch on the target site transmitter and switch off the old site transmitter at the right moment to prevent any break in the downlink audio path.

In a semiduplex system this is readily accomplished while the mobile telephone is transmitting. If the target site hears the mobile transmission it can immediately switch the transmitter on. When the mobile telephone stops the transmission the handover is already completed. To prevent any erroneous handover attempts due to interference or noise the target site must identify the mobile telephone in a reliable way.

The applicable technical standard requires the mobile telephone to send a special signalling message at the end of each transmission. This can be used for mobile identification if the transmitter switching is fast enough to enable full power output from the base station before the mobile telephone is able to receive. There are also other signalling messages used on the traffic channel during the call which can be used for this purpose and without the timing constraint above.

If the semiduplex mobile telephone is not transmitting it must detect the cable cut point and request the handover. It can be done by measuring the downlink signal level. If it drops below a specified level the mobile sends handover request messages until the level is increased. If the level stays low the call is released after several repeated attempts.

As soon as the system recognises a handover request message from a target site it switches the target site transmitter on and the old site transmitter off to complete the handover.

The reservation of a standby channel and a hardware channel unit on all target sites is another problem. Even if there are enough channels available the generous reservation method may limit the system capacity. On the other hand the use of additional channel units requires more hardware and more costs.

This problem can be helped with reducing the number of target sites and reducing the time that the standby channels are reserved.

The system holds a database of each user's handover privileges and only reserves standby channels on allowed target sites. If there are many types of users in the same system it is possible to define several user profiles that define the handover capabilities. The privileges may allow handover to all adjacent sites, to a limited number of sites or to no other sites.

As the principal users of an underground radio network are trains it is possible to predict the actual target site for the next handover. As the trains do not usually change direction the previous site is not a probable target site. The amount of crossings is very limited and so usually there is only one possible target site. Thus the handover channel is only needed there.

Some handportables which need to travel in any direction or route are given right to handover to any adjacent site. This means that handover standby channels need to be reserved on all of these sites.

On the other hand many handportables do not leave the station area at all. These are denied any handover rights and no standby channels need to be reserved. Furthermore, these units may share the same channel on adjacent sites, as there is no possibility of interference due to the cut cable principle.

The time that the standby resources are reserved can be reduced if the actual handover moment can be predicted. The standby channels can then be reserved "at the last moment".

Trains are bound to timetables and this may be used for predicting the handover moment. The accuracy depends on how punctual the trains are.

A more reliable timing method could involve the time that the train spends on each section of the track. The mobile telephone registers with standard procedures every time it changes from site to site. For each site the minimum time that the train must use on that section of the track can be calculated from the distance, the maximum speed and the

minimum stopping time. This "minimum site passing time" can be used to delay the reservation of the standby channel. Standby units are not reserved until the minimum site passing time has elapsed after the registration to this site.

If the station area is covered with a separate leaky feeder cable it may be possible to use a separate voting unit that is only connected to the station feeder and detect if the train is at the station. Thus the time it takes for the train to travel from the station to the cable cut could be predicted more accurately.

The mobile-assisted principle can be used also for predicting the handover moment. When the mobile telephone is able to detect the approaching handover point it can signal it to the system with a special message. The mobile can use several methods for this detection:

- If the average received signal level is steadily decreasing the train is moving away from the station.

- If the level drops below a certain level (eg the level that was measured when the mobile telephone registered to this site) the cable end is approaching.

- If the level drops below the minimum required level the cable cut was already passed. It may be too late to try any signalling to the old site so leaving the standby channel reservation to this point is risky.

- Special beacon transmitters can be located in the tunnel at a proper distance from the cable cut. This beacon is detected by the separate receiver and exact location can be given to the mobile.

The need for extra channel units due to the handover standby reservations can be reduced by allowing the allocation of these units to "real" calls on that site. The actual call handling capacity of the system is then not reduced due to the handover reservations but the probability of a failed handover is increased.

If after a call release the channel units are reserved immediately for any (queuing) handover standby use the limited hardware capacity is used in an optimum way.

The need for standby channel units can further be reduced by monitoring several standby channels in a time-shared fashion.

The most straightforward implementation of the invention is the combination of a prediction of the target site and the immediate standby unit reservation with release possibility to other calls.

Radio telephone systems according to the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representative of a first embodiment of the invention, and

Figure 2 is a diagrammatic representation of a second embodiment of the invention.

Referring to Figure 1 of the drawings, the radio telephone system comprises two base stations 1, 2 connected to a telephone exchange 7 and respectively serving two adjacent railway stations 3, 4 of an underground railway system. A tunnel bore 5 interconnects the railway stations 3 and 4 and a railway track 6 extends through the first railway station 3, through the tunnel bore 5 and through the adjacent railway station 4, it being assumed that this corresponds to the direction of travel of a train 8. A second tunnel bore (not shown) interconnects the railway stations and provides for train travel in the opposite direction, ie from station 4 to station 3.

A first radiating cable 9 extends from the base station 1 into the tunnel bore, terminating in a cut end 10. A second radiating cable 12 extends from the base station 2 into the tunnel bore, terminating in a cut end 13 positioned adjacent to cut end 10. As the train 8 proceeds through the bore, a mobile radio telephone 14 carried in or on the train 8

maintains a radio link with base station 1 by radio communication with the cable 9, which serves as an antenna. As the train approaches the cut end 10, so the signal strength received by the mobile telephone 14 falls and, in order to continue communication between the mobile telephone and the exchange, radio communication is transferred to the cable 12 in a call handover process. As the train passes through the region of the cut ends 10, 13, the received signal strength drops suddenly and handover must be effected rapidly to prevent substantial interruption of the call.

When communicating with base station 1, the radio telephone occupies a particular frequency channel. According to the invention, when call handover is anticipated, the same frequency channel has already been reserved at the next base station 2 (and possibly at additional base stations in a more complex railway network, see Figure 2).

When voice call set-up is completed successfully between the base station 1 and the telephone 14, the radio system infrastructure reserves the same channel as a standby channel at the target base station 2 immediately. As a result of this prior reservation, the receiver at the base station 2 is in a stand-by mode listening for a signal on the reserved channel. The transmitter at base station 2 remains turned off while the receiver is in stand-by mode.

When a mobile telephone 14 loses field strength on the original base station 1, it sends a handover request message on the traffic channel. The target base station 2, having a receiver on this channel, receives the message and can now turn its transmitter on and inform the infrastructure to change the channel unit on the base station 1 to the handover standby state. The infrastructure also releases any possible other handover standby channel units.

The handover request message is sent periodically by the radio telephone 14 while the received signal strength is under a particular level. If the radio telephone 14 does not get a better field strength during a predefined period, the mobile telephone releases itself from the channel.

The system performs the handover also if the target base station 2 receives any other identifiable signalling message from the mobile telephone 14.

The infrastructure decides to allocate a stand-by channel on a set of base stations based on the following data: underground train network structure, the mobile telephone handover privilege class and the sites where it operates at the moment as well as the previous site.

If the underground train system is divided into separate lines it may be possible to assign a mobile telephone to a single route semipermanently in the system database. Then only adjacent sites along that route need to be considered as possible handover target sites.

Mobile telephones in the form of handportable units are not tied to the same routes and their handover rights can be defined more freely. Some units may be given handover standby channels on all adjacent sites or a limited set of sites. Some units never need to leave their allocated station area and thus they do not need any standby channels.

The above standby channel allocation can be implemented with look-up tables where for each "present" and "previous" site pair the possible target sites are listed. Each mobile telephone is connected to a particular look-up table and the needed "previous" site information is stored in the system registration database.

Another possible implementation defines allowed routes as sequences of stations. Each mobile telephone is connected to one (or several) of these sequences.

A channel is allocated for standby channel use, if there is a free channel and a channel unit available on a "next" base station. If the channel or the channel unit is not available, the base station will get a queuing status. A subscriber can get a standby channel to a base station with queuing status, if a channel or a channel unit from this base station is released. The infrastructure checks if there are any subscribers who need this channel from this base station. If a subscriber needs the channel, the channel is allocated for standby channel use.

If the subscribers are on the same semiduplex call and they both need a standby channel on the same base station, the infrastructure can detect this and reserve the same channel for both subscribers. This way the channel capability is in more effective use.

Handover will fail onto a site where there is no channel unit and channel reserved as a handover standby channel.

If some other call needs the channel unit or the channel, which is in standby channel use, the radio path management subsystem can release the channel for normal traffic channel use. It is not possible to release the channel for the standby channel use.

Another method to improve the possibility of successful handover is to change the used channel before handover, if the current channel is not available on the "next" base station.

Figure 2 shows the invention applied to the intersection of two railway lines 15, 16 of an underground railway system. The line 15 has railway stations 17, 18, 19, and the line 16 has railway stations 20, 18 and 22, the station 18 being the intersection point of the two lines.

As in Figure 1 each railway station has a radio base station with a cable radiating from the base station into the tunnel bore. A portable handset on the train 23 on the line 15 at the position shown is in radio communication with the base station at railway station 17. When this radio link is established, the system reserves the same frequency channel as a stand-by channel at each of the possible target base stations, which in this example are the base stations at railway stations 18, 19, 20 and 22. It is necessary to treat the base stations at railway stations 20 and 22 as possible target base stations because the person carrying the portable handset could change onto line 16 at station 18. If the mobile radio is mounted in or on the train itself, the system can of course be more selective in choosing target base stations.

Reverting to the described example of the radio on the train being a portable handset, when a base station becomes a target base station, its receiver is placed in a stand-by mode

listening for a call from the portable handset on the reserved channel. The transmitter at each target base station remains off whilst the associated receiver is in the stand-by mode.

When a receiver at a target base station, in this case the base station at railway station 18, receives from the portable handset a call which is on the reserved channel, has a predetermined minimum signal strength and includes a satisfactory identification signal, call handover is effected, ie the transmitter is turned on at the target base station and the call (now established between the portable handset and the base station at railway station 18) continues. When handover is effected the base station at each of railway stations 17, 19, 20 and 22 becomes a target base station. At each new target base station, the receiver is placed in stand-by or listening mode and the transmitter is turned off or remains off. It should be noted that the base station at railway station 17 becomes a target base station because the carrier of the portable handset might change trains at station 18 and travel in the reverse direction towards railway station 17.

The invention was devised to facilitate call handover in a radio telephone system installed in an underground railway system. The methods can be adapted to other types of networks with some limitations. If the mobile telephones are moving mainly in one dimension (trains, highways, rivers) most of the inventive methods are applicable

CLAIMS

1. A radio telephone system comprising two base stations each of which has a transmitter and a receiver and which serve respective areas, and a mobile radio telephone movable with respect to the base stations so that as the mobile radio telephone moves out of the area served by the first base station and into the area served by the second base station a call handover procedure is effected, and control means for controlling the call handover procedure such that the setting up of a call on one channel between the mobile telephone and the first base station causes the receiver at the second base station to be in a stand-by mode listening for a call from the mobile radio telephone on said one channel, resulting in reservation of said one channel at the second base station, ready for the call handover procedure to be effected.

2. A radio telephone system according to claim 1, wherein the control means are operative to cause the transmitter at the second base station to be switched off or to remain switched off, whilst the receiver at the second base station is in the stand-by mode.

3. A radio telephone system according to claim 2, wherein the transmitter at the second base station is switched on when the receiver of the second base station receives from the mobile radio telephone a call which has a minimum predetermined signal strength and which includes a satisfactory identification signal.

4. A radio telephone system according to claim 3, wherein the mobile radio telephone produces the identification signal when the strength of the signal received by the mobile radio telephone falls below a predetermined threshold.

5. A radio telephone system according to any of the preceding claims, wherein the system is installed in an underground railway system.

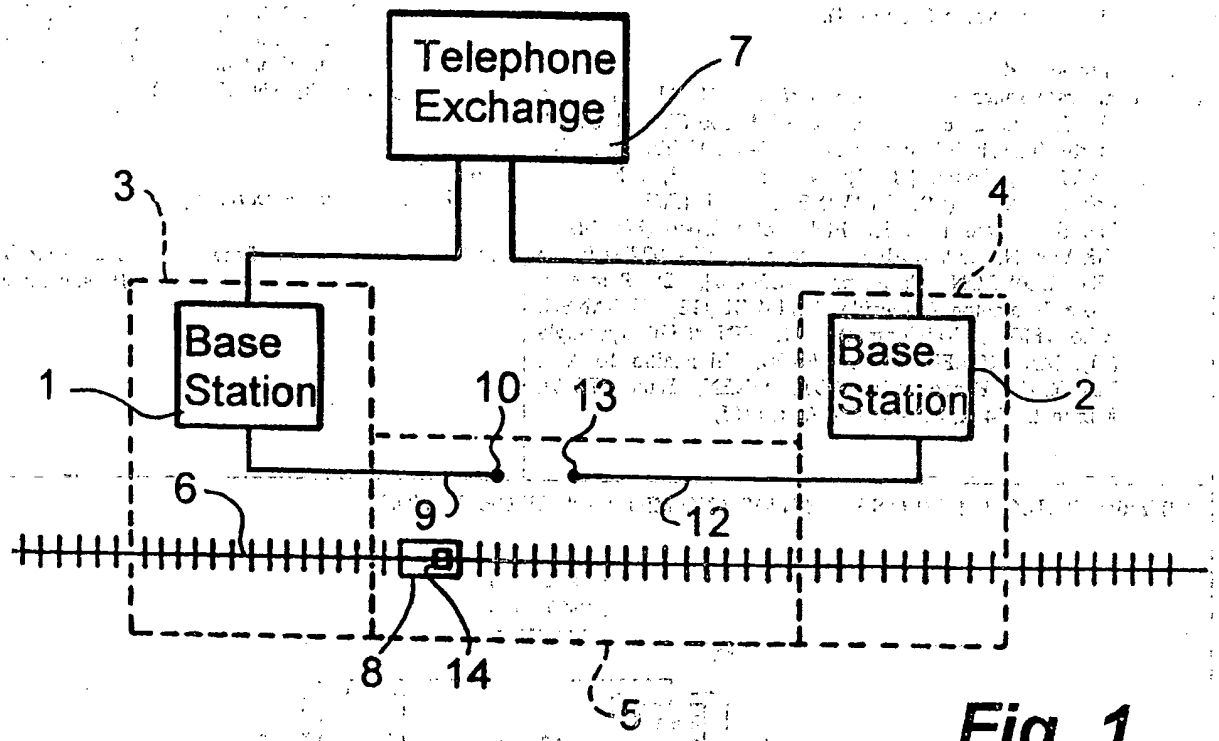
6. A radio telephone system according to claim 5, wherein the base stations are located at adjacent railway stations of the underground railway system, a tunnel bore interconnecting the railway stations and being served by radiating cables extending into the bore from the respective base stations.

7. A method of effecting call handover in a radio telephone system, comprising setting up a call on an available channel between a mobile telephone and a first base station and reserving the same channel at a second target base station where a receiver occupies a stand-by mode listening for a call from the mobile telephone on said one channel, ready for call handover when the mobile telephone moves from an area served by the first base station to an area served by the target base station.

8. A method according to claim 7, wherein on call handover the transmitter at the first base station is switched off and the receiver at the first base station assumes the stand-by mode.

9. A method according to claim 8, wherein on call set-up the channel is reserved at each of a plurality of possible target base stations, on call handover to a particular target base station the channel being released at the remaining target base stations.

10. A method according to claim 8 or 9, wherein the mobile telephone monitors received signal strength and transmits a handover request signal if the received signal strength falls below a predetermined level, the handover request signal being detected at the target base station and initiating call handover including the steps of switching on a transmitter of the target base station and switching off the transmitter of the first base station.


Telephone Exchange
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Base Station
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Base Station
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Fig. 1

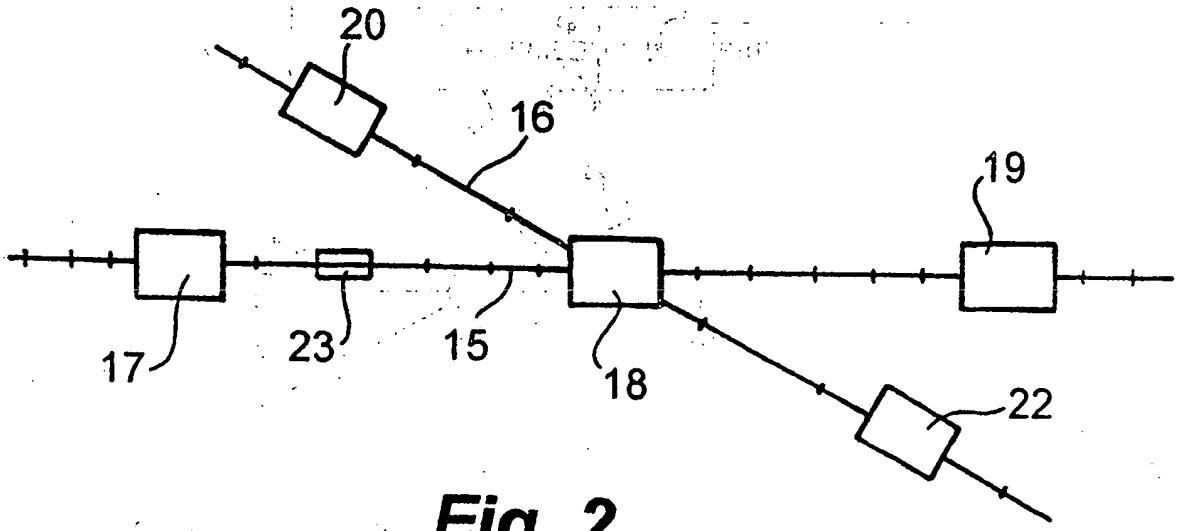
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Fig. 2

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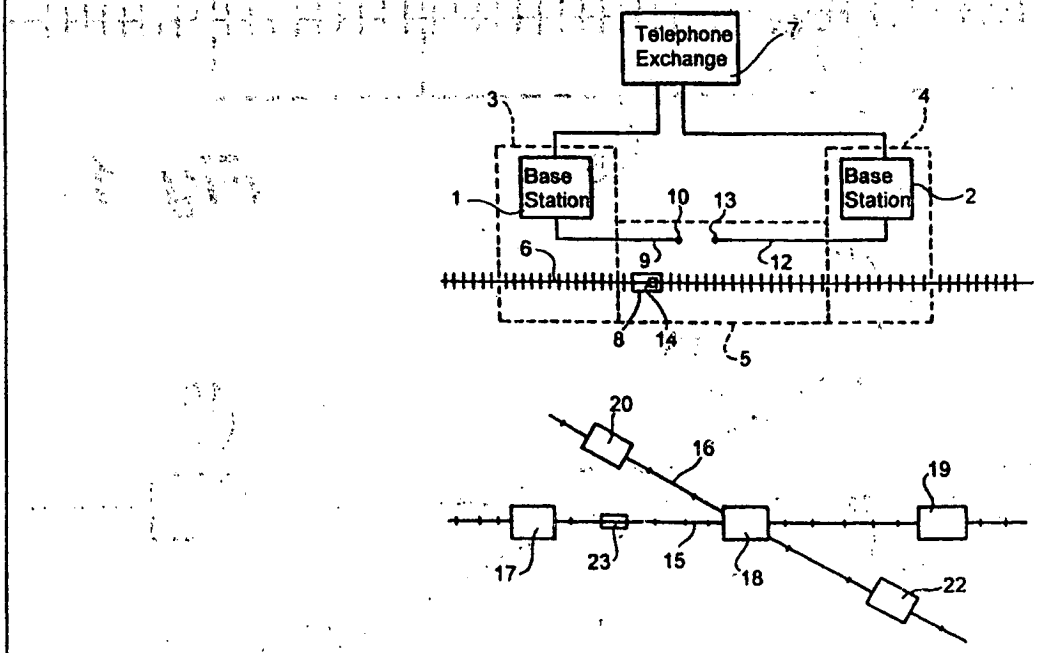

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INTERNATIONAL SEARCH REPORT

Internati Application No
PCT/GB 98/00369

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 726 425 A (ALCATEL MOBILE COMMUNICATION FRANCE SA) 3 May 1996 see page 7, line 30 - page 8, line 8 see page 7, line 22 - line 30 see page 8, line 30 - line 34	1-3,7-9
Y	see page 10, line 18 - line 22	4-6,10
Y	GB 2 302 481 A (NOKIA TELECOMMUNICATIONS OY) 15 January 1997 see page 1, line 31 see page 7, line 21 - line 25	5,6
Y	WO 96 19087 A (NOKIA TELECOMMUNCATIONS OY) 20 June 1996 see page 3, line 32 - line 35	4,10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
11 September 1998	18/09/1998

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Information on patent family members

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